MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 3, 2021/2022

EEE3106 – PROCESSING AND FABRICATION TECHNOLOGY

(EE)

11 AUGUST 2022
9.00 a.m - 11.00 a.m
(2 Hours)

INSTRUCTIONS TO STUDENTS

1. This Question paper consists of 7 pages with 4 Questions only.
2. Attempt **ALL** questions. The distribution of the marks for each question is given.
3. Please print all your answers in the Answer Booklet provided.
4. Please refer to the APPENDIX section on pages 6 and 7 for a list of physical constants, formulas, and the error function table.

Question 1

(a) Czochralski (Cz) is a mainstream method of growing single crystal semiconductor substrate materials for manufacturing of a wide range of microelectronic devices. Describe the crystal grow mechanisms of the Cz method. [2+8 marks]

(b) The CZ method is capable of producing large crystals. However, the method has inherent drawbacks in growing silicon (Si) crystals for microelectronic applications. Describe the origins of the drawbacks and its impact on the microelectronic applications. [6 marks]

(c) During a Cz crystal grow process, a Si ingot is pulled from the melt from the crucible loaded with Si and boron (B) dopants. After the crystal grow process, the Si ingot is sliced into thin wafers. The wafer sliced from the top of the ingot has a B concentration of 2×10^{16} cm^{-3}. The segregation coefficient (k) for the B is given as 0.8. Determine the doping concentration of the Si wafer taken from the position corresponding to 40 % of the initial charge solidified. [4 marks]

Continued .....

Question 2

(a) Describe the main steps of patterning process in microelectronic device fabrication. [5 marks]

(b) In an optical lithography process, a mask exposure system uses an *i*-line source with wavelength of 365 nm. If the photoresist thickness is 1.3 μm and the photoresist constant is 0.7, determine the minimum feature size, W_{min}, that can be achieved using a hard contact printing, and a proximity printing method with an air gap of 30 μm, respectively. Identify a suitable printing method among two methods here (contact and proximity) for device patterning design which prioritizes the device resolution. Explain the rationale behind the selection. [4+3 marks]

(c) Design a fabrication processing flow for the pattern depicted in Figure 2 (c) below, using lift-off and etch back method, respectively. [7 marks]

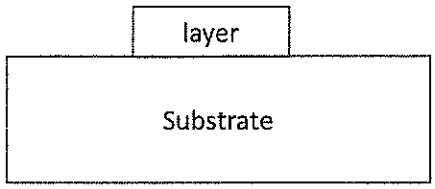

Figure 2 (c): A layer patterned on semiconductor substrate.

(d) Figure 2 (d) shows the schematic cross-sections (i & ii) of silicon (Si) substrates with patterned thermal oxide (SiO_2) layers. Design fabrication processes to realize the structures in Figure 2 (d), using negative photoresist for structure in (i), and positive photoresist for structure in (ii), respectively. Your designs should start from the Si substrate. Label each fabrication steps in your design. How many optical masks are required in the fabrication designs? [10+1 marks]

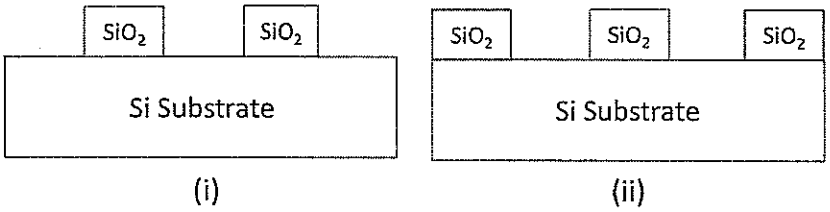

Figure 2 (d): Silicon substrates with thermal oxides.

Continued .....

Question 3

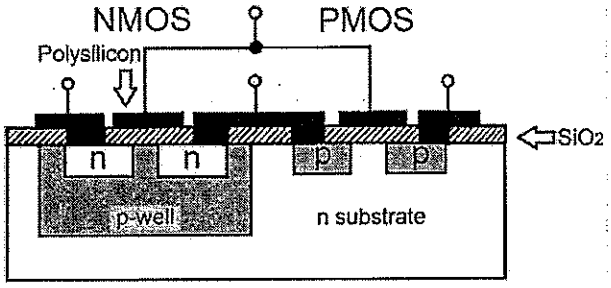

Figure 3(a): Schematic cross-section of a CMOS inverter.

(a) As a technology officer from a chip foundry, you are tasked to design a doping scheme for the realization of the complementary metal-oxide semiconductor (CMOS) inverter gate given in Figure 3(a). Propose a suitable doping scheme in your design and describe FIVE advantages of the doping scheme. [6 marks]

(b) In the design of the n and p-doped drain and source ohmic regions in Figure 3(a), imagine a 20 keV ion implantation is performed to form the ohmic regions of the CMOS inverter. The projected range of the implanted profile is 1000 Å. Given the standard deviation of the projected range as 200 Å. Determine the depth of peak of the implanted ohmic regions and the peak concentration for an implantation dose of 10^{15} cm^{-2}. [4 marks]

(c) In Figure 3(a), in order to form the p-well, the n-type silicon (Si) substrate with a background concentration of 1×10^{16} cm^{-3} is doped with boron (B) dopants using the drive-in diffusion process at a temperature of 1000 °C for 1 hour. At the end of the doping process, the B dopant concentration at the surface of the n-substrate is 5×10^{19} cm^{-3}. It is given that the diffusivity of B in Si is 1×10^{-16} cm^2s^{-1} at 1000 °C. Determine the dose of the B atoms for the diffusion process and the junction depth of the p-well region in the CMOS inverter given in Figure 3(a). [6 marks]

(d) Describe the main differences between the thermal diffusion process and ion implantation process. [4 marks]

Continued .....

Question 4

(a) Describe the following packaging steps in the back-end manufacturing processing of integrated circuit (IC).

(i) Die separation,
(ii) Die inspection,
(iii) Die attachment,
(iv) Wire bonding. [8 marks]

(b) Explain the epoxy die attachment and the eutectic die attachment method, respectively. Evaluate the potentials of these two methods in the context of the thermal performance of the IC packaging. [4+4 marks]

(c) Describe the pros and cons of plastic and ceramic IC packaging. Based on these characteristics, evaluate the potentials of the plastic and ceramic IC packaging in following applications.

(i) Military application,
(ii) Low power electronic applications,
(iii) Electronic products that are lightweight and small size,
(iv) Low cost electronic applications. [4+4 marks]

(d) In one IC foundry, a 450 mm wafer fabricated with dice has a defect density of 80 defects/cm^2 in that wafer. Each die on the wafer has a size of 5×5 mm^2. Assuming uniform defect density, determine the minimum market price for each die if the cost for testing and packaging each die is RM 2, while the total fabrication cost is RM 1000. Evaluate the profit margin if the targeted selling price for each die is RM 12.

[6 marks]

Continued .....

APPENDIX

Physical Constants:

Avogadro number, $N_{avo} = 6.02217\times10^{23}$ mol^{-1}
Boltzmann constant, k = 1.380622×10^{-23} J K^{-1} = 8.61712×10^{-5} eV K^{-1}
Electronic charge, e = 1.60219×10^{-19} C
Electron rest mass, $m_o = 9.10956\times10^{-31}$ kg
Electron volt, 1 eV = 1.60219×10^{-19} J
Si yield strength = 2×10^{7} dynes cm = 7 GPa
Latent heat of fusion for Si, L = 340 cal g^{-1}
Thermal conductivity of Si, k = 0.21 W cm^{-1} °C^{-1}
Amount of heat of 1 calorie = 4.14 J
Density of bulk Si = 2.33 g cm^{-3}
Density of molten Si = 2.53 g cm^{-3}
Electric current of 1 A = 1 Cs^{-1}
Atomic mass unit of 1 amu = 1.66053×10^{-27} kg
Magnetic flux density of 1 T = 1 Wb m^{-2} = 10^4 G
Angstrom unit of 1 Å = 1×10^{-10} m = 0.1 nm = 1×10^{-4} μm
Permittivity of free space = 8.85×10^{-14} F cm^{-1}
Pressure of 1 Torr = 133.32237 Pa

Formulas:

$C = kC_O(1-x)^{k-1}$	$C_S = \frac{Q_T}{\sqrt{\pi Dt}}$
$\boldsymbol{\sigma = pq\mu}$, $\rho = R_s \times t$,	$N(x) = \frac{Q_O}{\sqrt{2\pi}\Delta R_P} e^{\left[\frac{-1}{2}\left(\frac{x-R_P}{\Delta R_P}\right)^2\right]}$
$\boldsymbol{W_{min} = \sqrt{k\lambda g}}$ $W_{min}=K\{\lambda/NA\}$	$N(Rp) = \frac{Q_O}{\sqrt{2\pi}\Delta R_P}$
$C(x,t) = C_S\, erfc\left[\frac{x}{2\sqrt{Dt}}\right]$	$Y = \left[\frac{1-e^{-D_O A}}{D_O A}\right]^2$
$Q = 2C_S\sqrt{\frac{Dt}{\pi}}$	$Y = \left[\frac{1-e^{-2D_O A}}{2D_O A}\right]$
$C(x,t) = \frac{Q_T}{\sqrt{\pi Dt}} e^{-\frac{x^2}{4Dt}}$	$N = \frac{\pi(r-S)^2}{S^2}$
$RC = \frac{R_s L^2 \in_{gd}}{d_{gd}} = \frac{\rho}{d_{poly-si}} \frac{L^2 \in_{gd}}{d_{gd}}$	$Y = e^{-D_O A}$
$x_j = 2\sqrt{Dt\, \ln(N_0/N_B)}$	$x_j = 2\sqrt{Dt}\, erfc^{-1}(N_B/N_0)$

Continued .....

Values of the error function $\operatorname{erf}(t) = \frac{2}{\sqrt{\pi}} \int_0^t e^{-a^2} da$

t	0	1	2	3	4	5	6	7	8	9
0.0	0.000	0.0113	0.0226	0.0338	0.0451	0.0564	0.0676	0.0789	0.0901	0.1013
0.1	0.1125	0.1236	0.1348	0.1459	0.1569	0.1680	0.1790	0.1900	0.2009	0.2118
0.2	0.2227	0.2335	0.2443	0.2550	0.2657	0.2763	0.2869	0.2974	0.3079	0.3183
0.3	0.3286	0.3389	0.3491	0.3593	0.3694	0.3794	0.3893	0.3992	0.4090	0.4187
0.4	0.4284	0.4380	0.4475	0.4569	0.4662	0.4755	0.4847	0.4937	0.5027	0.5117
0.5	0.5205	0.5292	0.5379	0.5465	0.5549	0.5633	0.5716	0.5798	0.5879	0.5959
0.6	0.6039	0.6117	0.6194	0.6270	0.6346	0.6420	0.6494	0.6566	0.6638	0.6708
0.7	0.6778	0.6847	0.6914	0.6981	0.7047	0.7112	0.7175	0.7238	0.7300	0.7361
0.8	0.7421	0.7480	0.7538	0.7595	0.7651	0.7707	0.7761	0.7814	0.7867	0.7918
0.9	0.7969	0.8019	0.8068	0.8116	0.8163	0.8209	0.8254	0.8299	0.8342	0.8385
1.0	0.8472	0.8468	0.8508	0.8548	0.8586	0.8624	0.8661	0.8698	0.8733	0.8768
1.1	0.8802	0.8835	0.8868	0.8900	0.8931	0.8961	0.8991	0.9020	0.9048	0.9076
1.2	0.9103	0.9130	0.9155	0.9181	0.9205	0.9229	0.9252	0.9275	0.9297	0.9319
1.3	0.9340	0.9361	0.9381	0.9400	0.9419	0.9438	0.9456	0.9473	0.9490	0.9507
1.4	0.9523	0.9539	0.9554	0.9569	0.9583	0.9597	0.9611	0.9624	0.9637	0.9649
1.5	0.9661	0.9673	0.9684	0.9695	0.9706	0.9716	0.9726	0.9736	0.9746	0.9755
1.6	0.9764	0.9772	0.9780	0.9789	0.9796	0.9804	0.9811	0.9818	0.9825	0.9832
1.7	0.9838	0.9844	0.9850	0.9856	0.9861	0.9867	0.9872	0.9877	0.9882	0.9886
1.8	0.9891	0.9895	0.9899	0.9904	0.9907	0.9911	0.9915	0.9918	0.9922	0.9925
1.9	.99279	.99309	.99338	.99366	.99392	.99418	.99443	.99466	.99489	.99511
2.0	.99532	.99552	.99572	.99591	.99609	.99626	.99642	.99658	.99673	.99688
2.1	.99702	.99715	.99728	.99741	.99753	.99764	.99775	.99785	.99795	.99805
2.2	.99814	.99822	.99831	.99839	.99846	.99854	.99861	.99867	.99874	.99880
2.3	.99886	.99891	.99897	.99902	.99906	.99911	.99915	.99920	.99924	.99928
2.4	.99931	.99935	.99938	.99941	.99944	.99947	.99950	.99952	.99955	.99957
2.5	.99959	.99961	.99963	.99965	.99967	.99969	.99971	.99972	.99974	.99975
2.6	.99976	.99978	.99979	.99980	.99981	.99982	.99983	.99984	.99985	.99986
2.7	.99987	.99987	.99988	.99989	.99989	.99990	.99991	.99991	.99992	.99992
2.8	.99992	.99993	.99993	.99994	.99994	.99994	.99995	.99995	.99995	.99996
2.9	.99996	.99996	.99996	.99997	.99997	.99997	.99997	.99997	.99997	.99998
3.0	.99998	.99998	.99998	.99998	.99998	.99998	.99998	.99999	.99999	.99999

for t > 3 $\operatorname{erf}(t) \approx 1 - \frac{1}{\sqrt{\pi}\, t} \exp(-t^2)$

erfc (t) = 1 - erf (t)

End of Paper